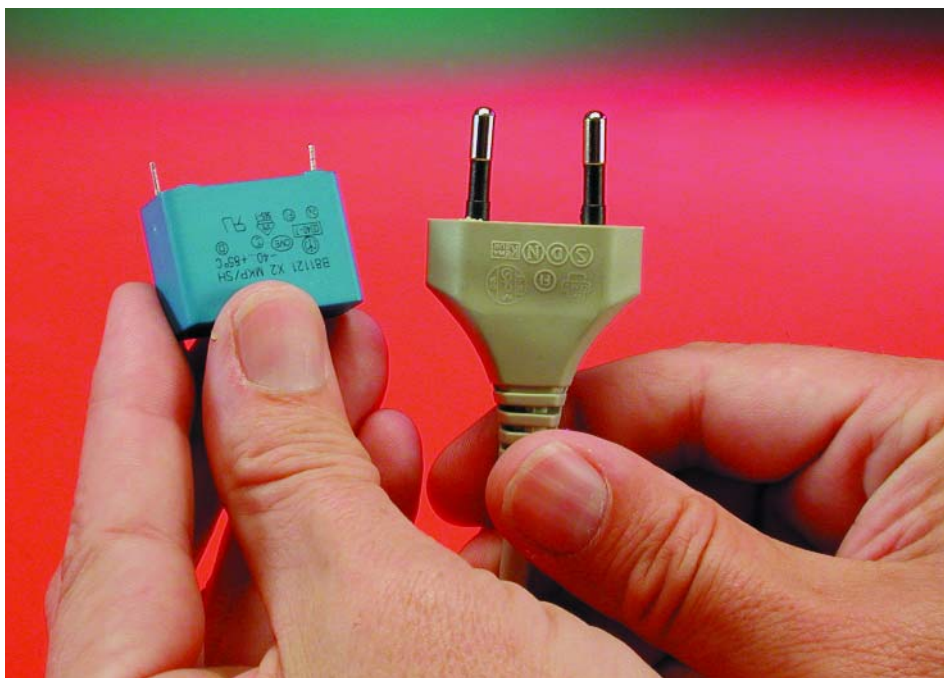


Capacitor as AC Voltage Dropper

transformerless power supply

By S. van Rooij

Some designs, because of lack of space or for some other reason, do not use a power supply transformer. Instead, an 'AC voltage dropper' in the shape of a capacitor is fitted. On more than one occasion readers have asked us the details of how this works and how the value should be calculated.



If the power supply for (part of) a circuit requires only a few milliamps from the mains the well-known 'transformerless' solution is frequently used. Here, a capacitor is used as an 'AC voltage dropper'. This method is not actually used all that often, because the advantage of the smaller size is offset by the

disadvantage of reduced electrical safety. Observe that the power supply is coupled directly to the mains and this is not really that elegant a solution, of course.

Nonetheless, an 'AC-voltage dropping resistor' can sometimes be a

convenient solution. One of the more recent occasions where we used such a transformerless power supply in *Elektor Electronics*, is the power-on delay for the Crescendo audio power amplifier. **Figure 1** shows the schematic for this design once more.

The exact details regarding the operation of this circuit are not relevant right now, but note that the 24-V relay Re1 is powered from the mains without the use of a transformer.

Capacitor C1 functions in this circuit as the AC-voltage-dropping-resistor. Resistors R1, R2 and R3 may obscure the picture somewhat, but they are of secondary importance in this instance. R1 and R2 make sure that C1 discharges when the mains power is switched off, and R3 limits the inrush current. The necessary voltage drop from 230 V to 24 V is achieved by C1 alone.

How does it work?

We cast our memory back to a bit of elementary theory. To illustrate how this AC voltage dropper works, a simple schematic has been drawn in

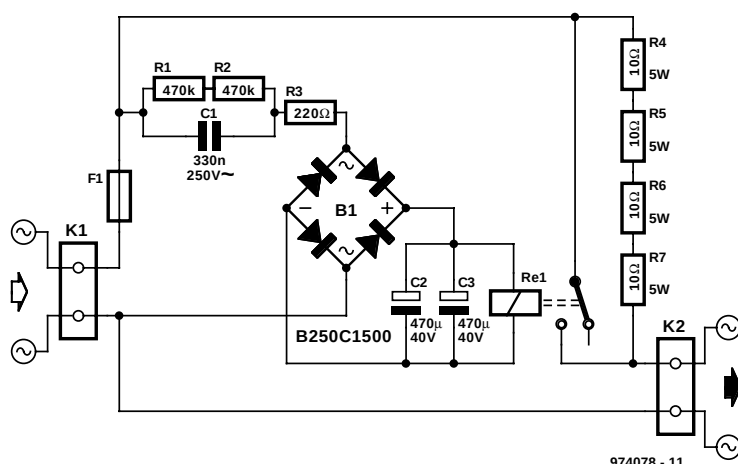


Figure 1. In this circuit, Re1 is powered directly from the mains by making use of 'AC voltage dropper' C1.

Figure 2. The whole circuit consists of a battery, two pushbuttons, a capacitor and a moving coil instrument.

If you activate button S1, the capacitor will charge and a current will flow, for a short period, through meter M. The needle will deflect briefly and then return to zero. If you now release S1 and subsequently push S2, the capacitor will discharge with the result that the needle of the meter will deflect briefly in the opposite direction.

We now take one more step and replace the battery with an AC voltage source. Because the polarity of the voltage is changing continuously, when S1 is held down, the capacitor will be repeatedly charged, discharged, charged in the opposite

direction, discharged and so on. The moving coil instrument M will therefore indicate a constant current. This current though, will continuously change direction at the same rate as the AC frequency. If the moving coil instrument is replaced with an AC ammeter (a multimeter in AC current mode) this will then indicate a constant value. From this we can conclude that capacitor C appears to behave just like a resistor. This apparent resistance to AC current is called the **capacitive reactance** of the capacitor. This reactance is frequency dependent and can be calculated using the formula

$$X_C = 1 / (2 \pi f C) \quad [\Omega]$$

In this formula, C is the capacitance

of the capacitor in Farad and f the frequency in Hertz.

Example

How do we calculate such an AC voltage dropper in practice?

For this purpose, let us briefly return to the circuit of **Figure 1**. The initial requirement is that the relay requires 24 V and therefore there has to be a voltage drop of some 200 V across capacitor C1. It is also necessary, of course, that we know the magnitude of the current that flows through the relay coil; for this type of relay this amounts to 20 mA.

Ohm's Law now permits the apparent resistance of the capacitor to be calculated: approximately 10 kΩ. Note that an actual resistor of this value would dissipate about 4 watts.

Once this is known, we can calculate the value of the capacitor with a rearranged version of the above mentioned formula:

$$C = 1 / (2 \pi f X_C)$$

We substitute for f the mains frequency of 50 Hz and end up with $1 / (2 \times 3.14 \times 50 \times 10^4) = 0.318 \mu\text{F}$. **Figure 1** shows that a value of 330 nF has been selected, which is very close to the theoretical one.

Of course, the capacitor that will be used here has to be rated for at least 250 V **alternating** current, while mains applications also require that an X2-class capacitor be used.

Limitations?

We already mentioned that the AC voltage dropper is used mainly when the current is limited to a few mA. Is there some reason or other why this method may not, or cannot, be used with larger currents?

In principle, no. Naturally, the voltage dropping capacitor will work equally well with larger currents as it does with small ones. However, the capacitor that will be required will keep growing in size as the current increases, and at some point it becomes more sensible to use a transformer instead. This transition point occurs at around 100 mA in practice. An X2 class capacitor with a rating of 1.5 μF/250 V~ is nearly the same size as a mains transformer rated 2×9 V/100 mA. At still larger currents, the space required for a high voltage, bipolar, foil capacitor would exceed that of a suitable transformer. Taking electrical safety into consideration as well, it obviously becomes preferable to use a transformer instead.

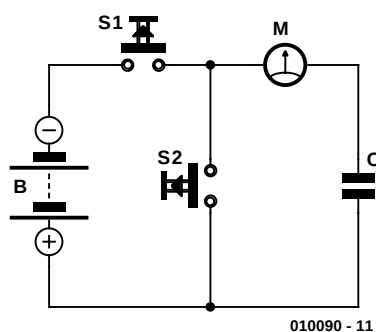


Figure 2. The operating principle can be easily demonstrated with the aid of this test circuit.

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